HNF-33614
Revision 0

Technical Basis Document of Marssim Field Calibration for Quantification of CS-137 Volumetrically Contaminated Soils in the BC Controlled Area Using a 4x4x16 Inch Sodium Iodide Detector

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Project Hanford Management Contractor for the
U.S. Department of Energy under Contract DE-AC06-96RL13200

FLUOR®
P.O. Box 1000
Richland, Washington

HNF-33614
Revision 0
EDC #: HNF-EDC-07-33615

Technical Basis Document of Marssim Field Calibration for Quantification of CS-137 Volumetrically Contaminated Soils in the BC Controlled Area Using a 4x4x16 Inch Sodium Iodide Detector

Document Type: TR Program/Project: S&GRP

J. L. Pappin
Fluor Hanford, Inc.

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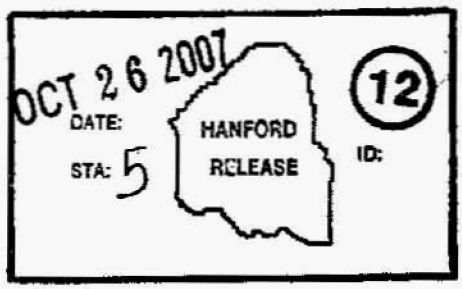

Release Approval 10/26/07 Date Release Stamp

Approved for Public Release;
Further Dissemination Unlimited

Total Pages: 63

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RECORD OF REVISION	(1) Document Number HNF-33614, Rev. 0	Page 1 of 1

(2) Title
Tech. Basis Doc. of Marssim Field Calibration for Quantification of CS-137 Volumetrically Contaminated Soils in the BC Controlled Area Using 4x4x16 Sodium Iodide Detectors

Change Control Record

(3) Revision	(4) Description of Change - Replace, Add. and Delete Pages	Authorized for Release (5) DA/TA Date
0 RS	This document provides the technical basis for calibrating a 4x4x16 Sodium Iodide Detector to quantify volumetrically contaminated soils. The algorithm developed converts instrument counts to pc:/g measurements. Changes per HNF-EDC-07-33615.	JGP 7/16/07

A-7320-005 (04/04)

TECHNICAL BASIS DOCUMENT OF MARSSIM FIELD CALIBRATION FOR QUANTIFICATION OF CS-137 VOLUMETRICALLY CONTAMINATED SOILS IN THE BC CONTROLLED AREA USING A 4X4X16 INCH SODIUM IODIDE DETECTOR

INTRODUCTION

The purpose of this paper is to provide the Technical Basis and Documentation for Field Calibrations of radiation measurement equipment for use in the MARSSIM Scoping Surveys of the BC Controlled Area (BCCA). The BC Controlled Area is bounded on the north by (but does not include) the BC Cribs & Trenches and is bounded on the south by Army Loop Road. Parts of the BC Controlled Area are posted as a Contamination Area and the remainder is posted as a Soil Contamination Area. The area is approximately 13 square miles and divided into three zones (Zone A, Zone B, and Zone C). A map from reference 1 which shows the 3 zones is attached. The MARSSIM Scoping Surveys are intended to better identify the boundaries of the three zones based on the volumetric (pCi/g) contamination levels in the soil. The MARSSIM Field Calibration, reference 2, of radiation survey instrumentation will determine the Minimum Detectable Concentration (MDC) and an algorithm for converting counts to pCi/g. The instrumentation and corresponding results are not intended for occupational radiation protection decisions or for the release of property per DOE Order 5400.5.

Based on the observed beta-gamma to alpha ratio, alpha surveys of the BC cribs and trenches, and the surrounding area are not required. The primary isotopes of concern are Cs-137 and Sr-90. Other isotopes are found only in trace amounts and are not considered to be significant. Although the Cs:Sr ratio may vary, both isotopes are present in all samples analyzed and found to be above background. This Cs tag allows the MARSSIM Scoping Surveys to be performed with gamma-only detection instrumentation. The calculated Cs-137 concentrations and survey locations will be used to identify the 41 and 12 pCi/g concentration boundary lines.

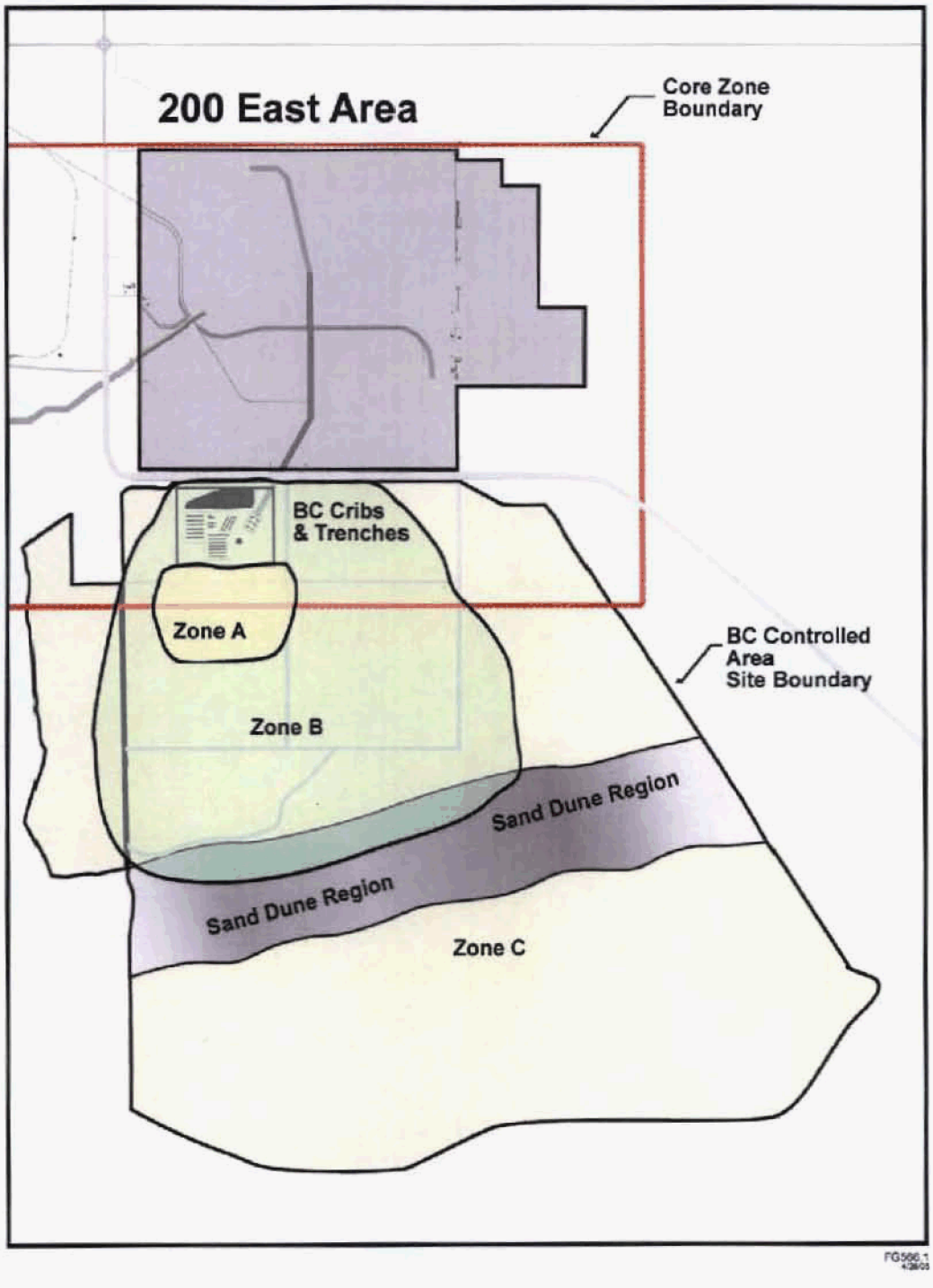
Evaluation of Current Conceptual Model and Zone Designations for BC Controlled Area.

- Current model has Zone A as most contaminated area with nearly continuous elevated radiological activity in surface soils. Assumed a remedial action will be needed in this zone. Soil concentrations of Cs-137 $\geq$ 41 pCi/g.
- Zone B is transitional in contamination levels and distribution of contamination. Some hot spots may be disseminated in the zone, particularly near Zone A boundary. Soil concentrations of Cs-137 are between 41 pCi/g and 12 pCi/g.
- Zone C is assumed to not to be contaminated above background levels. There are potential hot spots where animal scat was deposited. Soil concentrations of Cs-137 $\leq$ 12 pCi/g.

Reference 3 provides extensive documentation for the area. In the late 1950s through 1965 animal intrusion into the southern-most BC Trenches spread contamination from the area. An asphalt pad was placed over approximately 2/3rds of trench 216-B-28. In 1969 about 60,000 yd2 of sand and gravel were used to cover and stabilize the BC Trenches halting the spread of contamination from these sources by animals. In the late 1970s and early 1980s stabilization measures that had been taken in the 1960s failed and contamination was spreading primarily due to contaminated tumbleweeds. In 1981 the entire area of the cribs and trenches was covered with about 2 feet of soil and reseeded with vegetation designed to resist tumbleweed growth. This stabilization was judged to be effective on the surface of the crib. Contamination Transfer

Surveys of the BC Cribs in late 2004 found only one small area with transferable radioactive material on the surface of the BC Cribs and Trenches.

Current Conceptual Site Model Showing Contamination Zones Within the BC Controlled Area



MATERIALS & METHODS

Actual contaminated soil collected from the BC Controlled Area was used as the source for field calibration of radiological survey instruments to be used in the MARSSIM Scoping Surveys. Using a GM instrument, hotspots were located within the BC Controlled Area. The hottest of these locations contain the highest levels of contamination and were used as source material. As expected, the highest levels of contamination were located in Zone A. Once a hotspot was located, the contaminated soil was collected (shoveled) into a plastic 5 gallon bucket and transferred into a 55 gallon drum at the end of each shift, or whenever the plastic bucket became too full or heavy to handle.

The 55 gallon drum was moved to the RCT trailer near the southern boundary of the BC Controlled area. This trailer was used as a staging area for Field Calibration and MDC determination activities. Source preparation, background measurements, and field calibration measurements were all performed in this vicinity.

The contaminated soils were transferred to large tubs inside the trailer where it was dried and thoroughly mixed. Large rocks and other debris were removed from the contaminated soil during the mixing process. The mixing drying and sieving process continued until a uniform "source" material was created. Once direct measurements and tape presses confirmed the "source" material was uniformly mixed, samples were taken and sent to the lab for analysis.

The poly sample bottles used for samples sent to lab for gamma-spec analysis were also used for calibration sources. The 3" X 3" X 5 ½ " poly bottles were filled with the uniform source material. These containers will be used as calibration sources for the MARSSIM Field Calibration of radiological survey instrumentation. The results of the laboratory analysis will be used to determine the isotopic content of the calibration sources. Any unused source material was returned to the barrel.

A 4 X 4 X 16 inch NaI Detector, property tag # WD33787 was attached to an Ortec DigiBase Multichannel Analyzer. Ortec Search System Software was loaded onto a Panasonic Toughbook Laptop Computer, property tag # WD46885 to complete the instrument. Sodium Iodide (NaI) crystal gamma scintillators are primarily used for detecting high energy radiation in the range of 60 keV – 2 MeV. Some common applications for this type of detector include background radiation monitoring, high sensitivity surveying, and spectrum analysis when used in conjunction with a single or multi channel analyzer. These probes are only used to detect photons, but they may be sensitive to high energy beta radiation as well. The detectors are typically calibrated for Cs-137 (> 300 KeV Gamma). Because of their large signal and high gamma efficiency, these detectors can be used to detect gamma contamination with a high level of sensitivity. These detectors are typically used for the qualitative detection of contamination and not for the quantitative measurement of the amount of contamination.

The entire instrument was mounted on a John Deere Gator. The Detector and Multichannel Analyzer were mounted to the rear of the Gator in a metal box. The detector was positioned with the 16 inch side parallel to the surface of the ground and the rear of the Gator. Foam rubber cushioned the detector from mechanical shock, and a cooling system removed excess heat away from the Ortec DigiBase Multichannel Analyzer. The detector was shielded with lead on the top, sides, and one end to reduce unwanted background radiation and focus the instrument for the detection of ground contamination. The laptop computer was mounted in the cab of the Gator.

MARSSIM Field Calibration Measurements were performed with the radiological survey instrument as described above and identified in Attachment 3. This instrument will be used to perform the MARSSIM Scoping Surveys of the BC Controlled Area and the MARSSIM Field Calibration allows for the quantitative measurement of the amount of contamination. These measurements will be used with the laboratory isotopic analysis to determine the pCi/g algorithm and MDC for the radiological survey instruments. MARSSIM allows for one-time field calibration and does not require that this calibration be repeated. The instrument will be disassembled following the Scoping Surveys and any periodic re-calibration of the instrumentation is therefore not required. Six sample bottles containing the "source" material that was analyzed by the laboratory were used for the MARSSIM Field Calibration. The MDC calculation and conversion factor apply only to Cs concentrations. The bottles were buried side to side flush with the ground such that only the top side of the bottles were exposed. The source bottles, numbered 1 thru 6 e bottles were weighed so that the source strength could be determined. The bottom of the metal box containing the detector and mounted to the Gator was measured at 28 cm from the ground (46 cm to the center of the detector).

Two Methods were used for calibration purposes.

METHOD 1:

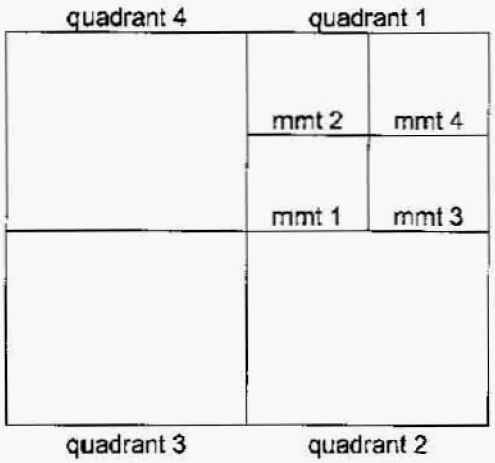
The Hotspot Program (developed by the University of California Lawrence Livermore National Laboratory under contract with the U.S. Department of Energy) contains a section devoted to FIDLER calibration. The FIDLER program is used to calibrate a FIDLER (Field Instrument for the Detection of Low-Energy Radiation) for measurement of plutonium contamination on the ground. However, the technique can be applied to any instrument suitable for measuring external radiation levels and non-plutonium mixtures, e.g. a NaI detection system for surveying 137Cs ground contamination. The FIDLER procedure describes a method for calibrating a detector to measure surface contamination with a single-point check source. Six radial measurement positions (0, 20, 40, 60, 80, and 100cm) are required for this calibration procedure. A series of measurements were taken by moving the detector and gator to each radial distance (0, 20, 40, 60, 80, and 100cm). Ten one second counts were taken at each radial distance. The total, full spectrum, gross counts were recorded, converted to a 60 second count total, and used for calibration purposes. The primary goal of the calibration procedure is to integrate the instrument's counting efficiency for an assumed uniform area contamination per square meter of surface. This parameter is referred to as the areal counting efficiency (Sa). This efficiency differs considerably from the simple point-source efficiency, which is commonly used to determine an instrument's sensitivity for locating small "point" sources. Here, we must account for the instrument's sensitivity for off-axis radiation sources and field of view.

The measurement results taken with the 4 X 4 x 16 inch NaI Instrument were analyzed using the FIDLER calibration program. The FIDLER analysis results were then used as the basis for calculating the MDC and uniform volumetric contamination algorithm. These are the values required by MARSSIM to show that the instrumentation is capable of measuring the necessary pCi/g levels as specified in reference 1.

METHOD 2:

A series of direct measurements were performed and equivalents assumed. The six sources were arranged in a 9" X 11" rectangle buried flush with the ground. The area was divided into 4 quadrants with the detector centered in the middle of the quadrants. A series of four measurements were taken in quadrant 1 as illustrated below. Each measurement was made with the 9' X 11" source array. Therefore, quadrant 1 measures a total of 18" X 22". Quadrant 1

measurements are assumed to be equivalent to measurements that could have been (but were not) performed in quadrants 2, 3, and 4. Quadrant 1 measurements are a conservative measure of source counts since the photomultiplier tube is located on the quadrants 3 and 4 side of the detector.



ASSUMPTIONS

All source material (contaminated soil) collected from the BCCA, dried, and blended is uniform. The samples sent to Fluor Hanford WESCF Analytical Chemistry for analysis contains identical volumetric contamination (activity/gram) as the soil remaining in the drum.

The 500 ml poly sample bottle sent to the lab for Cs-137 analysis measures 3" X 3" X 5 ½". Six of these bottles, filled with BCCA contaminated and characterized soil makes an appropriate source for calibrating a 4 X 4 X 16 inch2X2 NaI detector at 28 (46) cm. Burying the source bottles on their sides to a depth of 3 inches is assumed to be an accurate representation of BCCA contaminated soil.

FIDLER assumes that contamination lies entirely on the surface of the soil, characteristic of newly deposited activity. If significant weathering has occurred, a correction factor is required to account for the attenuation of the emitted photons as a function of soil depth. This correction factor should be based upon actual soil sample analyses. The source bottles as described above and buried on their sides is assumed to account for weathering and the attenuation of emitted photons as a function of soil depth (3 inches).

The Contamination is assumed to be uniformly distributed in the soil to a depth of 3 inches or equivalent to 7.5 cm. With a soil density of 1.6 g/cc, 10,000 cm2/m2, and 7.5 cm deep, the uniform volumetric contamination is 120,000 g/m2.

Instrumentation described above can be used for MARSSIM scoping surveys (pilot study) to determine volumetric contamination, pCi/g in the BCCA.

RESULTS & DISCUSSION

Analytical results from the soil samples sent to Fluor Hanford WSCF Analytical Chemistry are attached. The laboratory reported:

Cesium – 137	530 pCi/g +/- 84 pCi/g
Strontium – 89/90	460 pCi/g +/- 69 pCi/g

A Cesium : Strontium ratio of 1.15 is indicated by the sample results.

Since we know that the Cs – 137 sample mass was 923.2 grams (and that the same sample was used as our source in this calibration), then we calculate the source activity as:

SOURCE ACTIVITY = (5529.0 g) (530 pCi/g) = 2,930,370 pCi
OR
2.93 uCi

METHOD 1:

The FIDLER program was run for the source activity, geometry, and instrument using the average of the ten 1 second, full spectrum, gross accumulated counts at each radial position and at background with the source removed. The MARSSIM Field Calibration FIDLER program results printout is included as ATTACHMENT 3.

FIDLER results give us Detection Limits and Efficiency which we were then able to use in calculating MARSSIM Minimum Detectable Concentration ,MDC and the algorithm converting counts into pCi/g for field measurements. The calculation is given below.

Minimum Detectable Concentration =

$$\frac{\text{Area Detection Limit of 3.7 E-2 uCi/m2}}{\text{Soil Volume of 120,000 g/m2}} \text{ (1 E 6 pCi/uCi)}$$

= 0.308 pCi/g

And the conversion/calibration algorithm =

$$\frac{\text{Efficiency of 3.0 E 4 cpm/uCi/m2}}{\text{(Area Detection Limit of 3.7 E-2 uCi/m2)}}$$

MDC of 0.308 pCi/g

= 3604 cpm/pCi/g

OR

= 60 cps/pCi/g

METHOD2:

The four quadrant 1 measurements were made for the source activity, geometry, and instrument using the average of the ten 1 second, full spectrum, gross accumulated counts at each position and at background with the source removed. Results (averages) are given below:

POSITION	GROSS CPS -	BKG CPS	= NET CPS
1	2714	942	1772
2	1650	942	708
3	2057	942	1115
4	1457	942	515
	Total net CPS (all 4 positions)		*4110*
	X 4 quadrants	=>	*16,440 CPS*

and

$$\frac{16{,}440 \text{ CPS}}{530 \text{ pCi/g}} = \textbf{30 CPS/pCi/g}$$

SUMMARY/CONCLUSION

MARSSIM Field Calibration results are used to give us a calculated MDC of 0.308 pCi/g and 60 cps/pCi/g calibration factor. The MARSSIM Scoping Survey measurements in cps are divided by the calibration factor (cps/pCi/g) to convert measurements into volumetric contamination levels in pCi/g.

The field of view for the instrument was estimated by moving a sample bottle forward, backward, and side to side of the detector. The 0.308 pCi/g MDC and 60 cps/pCi/g calibration factor were

considered. The instrument detected the source at ~ 1 meter distance front and back and at ~ 30 cm side to side. The detector also saw the source along it's 16 inch, 41 cm length. Therefore, the instrument's field of view can be approximated as (41cm + 30cm + 30 cm) (100cm + 100cm) ~= to 20,000 cm2 or 2 square meters when the Gator is stationary.

Surveys will be performed in the BCCA on a grid with a survey point every 1 second. GPS equipment will be used to record location with the instrument readings. The continuous 1 second counts along transect lines will be downloaded into EXCEL. Background counts are subtracted from the gross counts to yield net counts above background. Dividing the net1 second counts by the calibration factor of 60 cps/pCi/g turns the data into pCi/g. The final result is pCi/g Cs-137 volumetric contamination for the measurement location.

Further sampling will be conducted in the BCCA to support and verify the surveys described above.

FIDDLER Error Analysis is summarized below

ERR0R ANALYSIS

ERROR		PERCENT	SQUARE
SOURCE ANALYSIS (WESCF) Cs-137	530 +/- 84	15.8	249.6
FIDLER CALIBRATION SDEV		1.6	2.6
SOURCE BOTTLE MAXIMUM WEIGHT DEVIATION FROM AVERAGE	922 + 102	11.1	123.2
SUM OF THE SQUARES			375.4
SQUARE ROOT OF THE SUM OF THE SQUARES			**19.40%**

Analysis of known sources of error associated with the FIDDLER calibration indicate an error of +/- 20%. The MARSSIM Field Calibration of the Gator Mounted 4 X 4 X 16 inch NaI detector calculates an MDC of 0.3 pCi/g and 60 cps/pCi/g (+/- 20% error). The Gator mounted instrument is able to measure the 12 and 41 pCi/g BCCA zone boundaries with >99% confidence.

The direct measurement and equivalents method calculates 30 CPS/pCi/g over an area of 1.02 square meters. This is considered to be the most conservative number to calculate and measure the 12 and 41 pCi/g BCCA zone boundaries. The number we will use for this calibration is:

30 CPS/pCi/g

ATTACHMENTS

1. Chemistry results

2. Hotspot Program, FIDLER Calibration Description

3. FIDLER Field Calibration run

REFERENCES

1. DOE/RL-2004-39 Revision 0 200-UR-1 Unplanned Release Waste Group Operable Unit RI/FS Work Plan
2. DOE/EH-0624, Rev. 1 Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)
3. WMP-18647 Historical Site Assessment of the Surface Radioactive Contamination of the BC Controlled Area, May 2004

Approval Signatures:

J. L. Pappin — Date 6/26/07

S. D. Landsman — Date 6/26/07

B. L. Baumann — Date 7/3/07

J. B. Stamper — Date 7/11/07

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Fluor Hanford
WSCF Analytical Chemistry
P.O. Box 1000
Richland, WA 99352
Telephone 373-7495
Telefax 372-0456

FLUOR

Memorandum

M8141-SLF-06-062

To: S. J. Trent A0-21 Date: March 28, 2006

From: S. L. Fitzgerald, Manager
WSCF Analytical Chemistry

cc: w/Attachments
T. F. Dale S3-30
H. K. Meznarich S3-30
P. D. Mix S3-30
J. E. Trechter S3-30
File/LB

Subject: FINAL RESULTS FOR BC CONTROLLED AREA SAMPLE – SAMPLE DELIVERY GROUP WSCF20060197 – SAF NUMBER F06-013

Reference: (1) Groundwater Protection Program-Letter of Instruction, FH-EIS-2003-MEM-001, October 31, 2002

(2) HNF-SD-CD-QAPP-017, Rev. 7, Waste Sampling & Characterization Facility Quality Assurance Plan

This letter contains a narrative (Attachment 1) for sample delivery group WSCF20060197, the analytical results (Attachment 2), and the sample receipt information (Attachment 3).

SLF/grf

Attachments 3

M8141-SLF-06-062

ATTACHMENT 1

NARRATIVE

Consisting of 3 pages
Including cover page

Attachment 1
Narrative

Sample Delivery Group	**WSCF20060197**
Sample Matrix	**SOIL**
Sample Visual	**N/A**
SAF Number	**F06-013**
Data Deliverable	**Summary Report**

Introduction

One (1) BC Controlled Area sample (B1HTJ7) was received at the WSCF Laboratory on March 21, 2006. The sample was analyzed for the analyte indicated on the attached copy of the chain of custody (COC) form in accordance with the *Groundwater Remediation Program – Letter of Instruction*, referenced in the cover letter.

The narrative (Attachment 1) will address sample characteristics, analyses requested and general information in performance of the analytical methods. A Data Summary Report (Attachment 2) includes analytical results, a comment report detailing method abnormalities, tentatively identified peaks if applicable, method references, and Laboratory QC information. Copies of the chain of custody and sample receipt are included as Attachment 3.

Analytical Methodology for Requested Analyses

Refer to WSCF Method References Report, page 11, for a complete listing of approved analytical methods.

Radiochemical Comments

RadChem – There are no hold times associated with WSCF radiochemical methods. A Blank, Laboratory Control Sample and Duplicate QC sample were analyzed with each delivery group per the GRP Letter of Instruction. See page 8 for QC details.

All QC controls are within established limits.

This Summary Report is in compliance with the SOW, both technically and for completeness. Release of the data contained in this hard copy report has been authorized by the WSCF Laboratory Analytical Manager and Client Services, as verified by the following signature.

Pauline D. Mix
WSCF Client Services

Abbreviations
Hg – mercury
IC – ion chromatography
ICP – inductively coupled plasma
ICP/AES – ICP/atomic emission spectroscopy
ICP/MS – ICP/mass spectrometry
Total U – total uranium
AT/TB – total alpha/total beta
AEA – Alpha Energy Analysis
WTPH-G – Total Hydrocarbons-Gasoline

Am – americium
Cm - curium
Pu – plutonium
Np – neptunium
GEA – gamma energy analysis
H3 – Tritium
Sr – Strontium 89, 90
WTPH-D – Total Hydrocarbons-Diesel
TSS – Total Suspended Solids

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ATTACHMENT 2

ANALYTICAL RESULTS

Consisting of 8 pages
Including cover page

WSCF
ANALYTICAL RESULTS REPORT

for

Groundwater Remediation Program

Richland, WA 99354

Attention: Steve Trent

Analytical: S. Fitzgerald

Client Services: CBj 3.29.Mar 3/27/2006

All results are reported on an "as received" basis unless otherwise noted in the comment section.

Contract#: FH-EIS-2003-MEM-001
Report#: WSCF20060197
Report Date: 27-mar-2006
Report WGPPver. 1.3
Groundwater Remediation Program

WSCF
ANALYTICAL RESULTS REPORT

Attention: Steve Trent
Project: F06-013: F06-013

Group #: WSCF2006O197

Sample #	Client ID		CAS #	Test Performed	Matrix	WSCF Method	RQ	Result	Unit	DF	MDL	Analyze	Sample	Receive
Radiochemistry														
W0600000476	81HTJ7	TRENT	10045-97-3	Cesium-137	SOIL	LA-508-481		530	pCi/g	1.00	0.17	03/22/06	03/21/06	03/21/06
W0600000476	81HTJ7	TRENT	E,T,C	Cs-137 Rel. Count Error (GEA)	SOIL	LA-508-481	+-	84	pCi/g	1.00	0.0	03/22/06	03/21/06	03/21/06

MDL = Minimum Detection Limit
RQ = Result Qualifier

DF = Dilution Factor

* - Indicates results that have NOT been validated; + - Indicates more than six qualifier symbols

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WSCF ANALYTICAL LABORATORY QC REPORT

SDG Number: WSCF20060197
Matrix: SOLID
Test: Gamma Energy Analysis-grd H2O

SAF Number: F06-013
Sample Date: 03/21/06
Receive Date:03/21/06

QC Type	Analyte	CAS #	QC Found	QC Yield	Units	Analysis Date	Lower Limit	Upper Limit	RQ
Lab ID: W060000476									
BATCH QC ASSOCIATED WITH SAMPLE									
DUP	Cesium-137	10045-97-3	5.32e+02	0.188	RPD	03/22/06	0.000	20.000	
BATCH QC									
BLANK	Cesium-137	10045-97-3	U-3.1e-4	n/a	pCi/g	03/22/06	-10.000	1000.000	
LCS	Cesium-137	10045-97-3	4.01e+03	112.011	% Recov	03/22/06	80.000	120.000	

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WSCF
ANALYTICAL COMMENT REPORT

Attention:
Project Number

Group #: 20060197

Sample #	Client ID	Lab Area	Test	Comment

Lab Areas: VALGROUP - Group Validation
LOGSAMP - Login for Sample
VALTEST - Test Validation
LOGTEST - Login for Tests
TESTDATA - Test Data Entry

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WSCF

TENTATIVELY IDENTIFIED PEAK REPORT

Attention: Steve Trent
Project Number F06-013 :F06-013

Group #: WSCF20060197

Sample #	Client ID		Test Name	Peak Name	CAS#	RT	RQ	Result	Units
W060000476	B1HTJ7	TRENT	Gamma Energy Analysis-grd H2O	K-40 Count Error				14	%
W060000476	B1HTJ7	TRENT	Gamma Energy Analysis-grd H2O	AC-228 Count Error				32	%
W060000476	B1HTJ7	TRENT	Gamma Energy Analysis-grd H2O	RA-228 Count Error				32	%
W060000476	B1HTJ7	TRENT	Gamma Energy Analysis-grd H2O	AC-228				0.60	pCi/g
W060000476	B1HTJ7	TRENT	Gamma Energy Analysis-grd H2O	RA-228				0.60	pCi/g
W060000476	B1HTJ7	TRENT	Gamma Energy Analysis-grd H2O	K-40				13	pCi/g

RQ=Result Qualifier

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WSCF
METHOD REFERENCES REPORT

The results provided in this report were generated using the following WSCF Laboratory procedures. For your convenience, this table provides a listing of the regulatory or industry methods that are referenced by each of these WSCF procedures. Please note that the most recent version of the regulatory or industry method is listed here even though the WSCF procedure may reference an older version of the method. Also, a reference to a regulatory or industry method here does not necessarily indicate a verbatim implementation of that method.

LA-508-481 LA-508-481: GAMMA ENERGY ANALYSIS USING PROCOUNT SOFTWARE

None — No reference to any industry method.

Note: A complete list of WSCF analytical procedures and referenced regulatory or industry methods is available online at \\ap006\aspdocs\WSCF\Sample Mgmt\ProcedureMethodCrossReference.pdf. This document includes on-line links to full-text versions of the procedures and methods, where available.

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w13qlog v1 27-mar-2006 06:39:45

W13q Worklist/Batch/QC Report for Group# WSCF20060197

WL#	S#	Batch	QC#	Tray Type	Sample#	Test
28294	1	28666	32501	BLANK		Gamma Energy Analysis-grd H2O
28294	2	28666	32501	LCS		Gamma Energy Analysis-grd H2O
28294	3	28666	32501	DUP	W060000476	Gamma Energy Analysis-grd H2O
28294	4	28666	32501	SAMPLE	W060000476	Gamma Energy Analysis-grd H2O

M8141-SLF-06-062

ATTACHMENT 3

SAMPLE RECEIPT INFORMATION

Consisting of 4 pages
Including cover page

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Waste Sampling and Characterization Facility
P.O. BOX 1970 S3-30, Richland, WA 99352
PHONE: (509) 373-7004/FAX: (509) 373-7134

4/20/06

ACKNOWLEDGMENT OF SAMPLES RECEIVED

File 1CB

Groundwater Remediation Program
Richland, WA 99354
Attn: Steve Trent

Customer Code: GPP
PO#: 121640/ES10
Group#: 20060197
Project#: F06-013
Proj Mgr: Steve Trent A0-21
Phone: 373-5869

The following samples were received from you on 03/21/06. They have been scheduled for the tests listed beside each sample. If this information is incorrect, please contact your service representative. Thank you for using Waste Sampling and Characterization Facility.

Sample#	Sample Id	Tests Scheduled	Matrix	Sample Date
W060000476	B1HTJ7	TRENT @GEA-GPP	Solid, or handle as if solid	03/21/06

Test Acronym Description

Test Acronym	Description
@GEA-GPP	Gamma Energy Analysis-grd H2O

Fluor Hanford Inc.

4/20

CHAIN OF CUSTODY/SAMPLE ANALYSIS REQUEST

F06-013-002 | PAGE 1 OF 1

COLLECTOR: Deb Alexander / Jeff Pappin	COMPANY CONTACT: TRENT, SJ	TELEPHONE NO.: 373-5869	PROJECT COORDINATOR: TRENT, SJ
SAMPLING LOCATION: BC Controlled Area	PROJECT DESIGNATION: BC Cribs - Sodium Iodide Standard Analysis		SAF NO.: F06-013
ICE CHEST NO.: GRP-05-009	FIELD LOGBOOK NO.:	COA: 121640ES10	METHOD OF SHIPMENT: GOVERNMENT VEHICLE
SHIPPED TO: Waste Sampling & Characterization	OFFSITE PROPERTY NO.:		BILL OF LADING/AIR BILL NO.:

PRICE CODE: 8N | AIR QUALITY: ☐ | DATA TURNAROUND: 45 Days / 45 Days

MATRIX*: A=Air, DL=Drum Liquids, DS=Drum Solids, L=Liquid, O=Oil, S=Soil, SE=Sediment, T=Tissue, V=Vegitation, W=Water, WI=Wipe, X=Other

POSSIBLE SAMPLE HAZARDS/ REMARKS:

SPECIAL HANDLING AND/OR STORAGE: 20060197

PRESERVATION	None
TYPE OF CONTAINER	Square Bottle - Poly
NO. OF CONTAINER(S)	1
VOLUME	500mL
SAMPLE ANALYSIS	Gamma Spectroscopy (Cesium-137)

SAMPLE NO.	MATRIX*	SAMPLE DATE	SAMPLE TIME	
B1HTJ7	SOIL	3/16/06	1300	✓
W06 000476		21		
		AJA 3-21-06		

CHAIN OF POSSESSION / SIGN/ PRINT NAMES

RELINQUISHED BY/REMOVED FROM	DATE/TIME	RECEIVED BY/STORED IN	DATE/TIME
D Alexander/Pappin	3-21-06/1334	[illegible]	3/21/06 1334

SPECIAL INSTRUCTIONS

Sieved sample of BC Controlled Area calibration soil

Lab is to return undisturbed sample to client
Jeff Pappin
(509) 946-1376 Ext. 201

LABORATORY SECTION: RECEIVED BY | TITLE | DATE/TIME

FINAL SAMPLE DISPOSITION: DISPOSAL METHOD | DISPOSED BY | DATE/TIME

A-6003-618(01/06)

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WASTE SAMPLING AND CHARACTERIZATION FACILITY (WSCF)

NOTICE OF IMPROPER SAMPLE SUBMITTAL

Customer Name: Steve Trent

Sample ID: BHT17 Date Received: 5/21/06

Project Contact: Steve Trent Phone Number: 373-5869

- [X] Sample not iced.
- [ ] Sample does not pass radiological screening.
- [ ] Sample not accompanied by a Chain of Custody (COC) or Request for Special Analysis (RSA).
- [ ] Improperly completed COC or RSA.
- [ ] Sample information does not agree with documentation.
- [ ] Handwriting is illegible.
- [ ] Sample container broken/leaking.
- [ ] Sample container not labeled/label unreadable.
- [ ] Sample received with custody seal broken.
- [ ] Sample improperly packaged.
- [ ] Improper sample container for analyses requested.
- [ ] Insufficient sample quantity for requested analyses.
- [ ] Holding time exceeded.
- [ ] Other (see below)

Comments: _____

_____

_____

_____

For information on proper sample submittal procedures, contact WSCF Sample Custodian at 373-7423, 373-7001, or Sample Receiving at 373-7019.

Signature: _____ Date: _____

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Fluor Hanford
WSCF Analytical Chemistry
P.O. Box 1000
Richland, WA 99352
Telephone 373-7495
Telefax 372-0456

FLUOR

Memorandum

M8141-SLF-06-075

To: S. J. Trent A0-21 Date: April 18, 2006

From: S. L. Fitzgerald, Manager
WSCF Analytical Chemistry

cc: w/Attachments
T. F. Dale S3-30
H. K. Meznarich S3-30
P. D. Mix S3-30
J. E. Trechter S3-30
File/LB

Subject: FINAL RESULTS FOR BC CONTROLLED AREA SAMPLE WITH REVISED SAMPLE IDENTIFICATION NUMBER – SAMPLE DELIVERY GROUP WSCF20060211 – SAF NUMBER F06-013

Reference: (1) Memo, SL Fitzgerald to SJ Trent, same subject (M8141-SLF-06-068), dated April 6, 2006

(2) Groundwater Protection Program-Letter of Instruction, FH-EIS-2003-MEM-001, October 31, 2002

(3) HNF-SD-CD-QAPP-017, Rev. 7, Waste Sampling & Characterization Facility Quality Assurance Plan

This letter contains a revised narrative (Attachment 1), the analytical results (Attachment 2) with the revised sample identification number, and revised sample receipt information (Attachment 3) for sample delivery group WSCF20060211.

Please note that this submittal supersedes Reference 1 in its entirety. If you have any questions, don't hesitate to call on Pauline Mix, telephone 372-1488, for assistance.

SLF/grf

Attachments 3

M8141-SLF-06-075

ATTACHMENT 1

NARRATIVE

Consisting of 3 pages
Including cover page

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Attachment 1
Narrative

Sample Delivery Group	**WSCF20060211, Rev. 1**
Sample Matrix	**SOIL**
Sample Visual	**N/A**
SAF Number	**F06-013**
Data Deliverable	**Summary Report**

Introduction

One (1) BC Controlled Area sample (B1HTJ7-A) was received at the WSCF Laboratory on March 23, 2006. The sample was analyzed for the analyte indicated on the attached copy of the chain of custody (COC) form in accordance with the *Groundwater Remediation Program – Letter of Instruction*, referenced in the cover letter.

The narrative (Attachment 1) will address sample characteristics, analyses requested and general information in performance of the analytical methods. A Data Summary Report (Attachment 2) includes analytical results, a comment report detailing method abnormalities, tentatively identified peaks if applicable, method references, and Laboratory QC information. Copies of the chain of custody and sample receipt are included as Attachment 3.

Analytical Methodology for Requested Analyses

Refer to WSCF Method References Report, page 11, for a complete listing of approved analytical methods.

Radiochemical Comments

RadChem – There are no hold times associated with WSCF radiochemical methods. A Blank, Laboratory Control Sample and Duplicate QC sample were analyzed with each delivery group per the GRP Letter of Instruction. See page 8 for QC details.

All QC controls are within established limits.

Strontium-85 – Radiochemical Tracer Recovery Data are summarized below:

Radiochemical Tracer Percent Recovery			
Sample Number	**Lab Sample ID**	**Isotope**	**Tracer Recovery**
Strontium-85			
BLANK		Sr-85	86.8%
LCS		Sr-85	75.0%

Radiochemical Tracer Percent Recovery			
Sample Number	**Lab Sample ID**	**Isotope**	**Tracer Recovery**
B1HTJ7-A	W060000492	Sr-85	105.2%
DUPLICATE	W060000492	Sr-85	105.8%

This Summary Report is in compliance with the SOW, both technically and for completeness. Release of the data contained in this hard copy report has been authorized by the WSCF Laboratory Analytical Manager and Client Services, as verified by the following signature.

Pauline D. Mix
WSCF Client Services

Abbreviations

Hg – mercury
IC – ion chromatography
ICP – inductively coupled plasma
ICP/AES – ICP/atomic emission spectroscopy
ICP/MS – ICP/mass spectrometry
Total U – total uranium
AT/TB – total alpha/total beta
AEA – Alpha Energy Analysis
WTPH-G – Total Hydrocarbons-Gasoline
Am – americium
Cm - curium
Pu – plutonium
Np – neptunium
GEA – gamma energy analysis
H3 – Tritium
Sr – Strontium 89, 90
WTPH-D – Total Hydrocarbons-Diesel
TSS – Total Suspended Solids

M8141-SLF-06-075

ATTACHMENT 2

ANALYTICAL RESULTS

Consisting of 8 pages
Including cover page

WSCF
ANALYTICAL RESULTS REPORT

for

Groundwater Remediation Program

Richland, WA 99354

Attention: Steve Trent

Analytical: S. Fitzgerald

Client Services: GDay 4/18/2006

All results are reported on an "as received" basis unless otherwise noted in the comment section.

Contract#: FH-EIS-2003-MEM-001
Report#: WSCF20060211
Report Date: 18-apr-2006
Report WGPP/ver. 1.3
Groundwater Remediation Program

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WSCF
ANALYTICAL RESULTS REPORT

Attention: Steve Trent
Project: F06-013: F06-013

Group #: WSCF20060211

Sample #	Client ID			CAS #	Test Performed	Matrix	WSCF Method	RQ	Result	Unit	DF	MDL	Analyze	Sample	Receive
Radiochemistry															
W060000492	B1HTJ7-A	GRP	TRENT	SR-RAD	Strontium-89/90	SOIL	LA-508-415		460	pCi/g	1.00	0.31	03/30/06	03/21/06	03/23/06
W060000492	B1HTJ7-A	GRP	TRENT	E,T,C	Sr-89/90 Rel. Count Error	SOIL	LA-508-415	+-	69	pCi/g	1.00	0.0	03/30/06	03/21/06	03/23/06

MDL = Minimum Detection Limit
RQ = Result Qualifier

DF = Dilution Factor

* - Indicates results that have NOT been validated; + - Indicates more than six qualifier symbols

Report WGPP/ver. 1.3
Groundwater Remediation Program

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WSCF ANALYTICAL LABORATORY QC REPORT

SDG Number: WSCF20060211
Matrix: SOLID
Test: Strontium 89/90

SAF Number: F06-013
Sample Date: 03/21/06
Receive Date:03/23/06

QC Type	Analyte	CAS #	QC Found	QC Yield	Units	Analysis Date	Lower Limit	Upper Limit	RQ
Lab ID: W060000492									
BATCH QC ASSOCIATED WITH SAMPLE									
DUP	Strontium-89/90	SR-RAD	4.9e+02	6.316	RPD	03/30/06	0.000	20.000	
BATCH QC									
BLANK	Strontium-89/90	10098-97-2	7.6e-02	0.076	pCi/g	03/30/06	-10.000	300.000	
LCS	Strontium-89/90	10098-97-2	67.9	101.860	% Recov	03/30/06	80.000	120.000	

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WSCF
ANALYTICAL COMMENT REPORT

Attention:
Project Number

Group #: 20060211

Sample #	Client ID	Lab Area	Test	Comment

Lab Areas: VALGROUP - Group Validation
LOGSAMP - Login for Sample
VALTEST - Test Validation
LOGTEST - Login for Tests
TESTDATA - Test Data Entry

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WSCF
TENTATIVELY IDENTIFIED PEAK REPORT

Attention:
Project Number :

Group #: 20060211

Sample #	Client ID	Test Name	Peak Name	CAS#	RT	RQ	Result	Units

RQ=Result Qualifier

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WSCF
METHOD REFERENCES REPORT

The results provided in this report were generated using the following WSCF Laboratory procedures. For your convenience, this table provides a listing of the regulatory or industry methods that are referenced by each of these WSCF procedures. Please note that the most recent version of the regulatory or industry method is listed here even though the WSCF procedure may reference an older version of the method. Also, a reference to a regulatory or industry method here does not necessarily indicate a verbatim implementation of that method.

LA-508-415 LA-508-415: OPERATION OF THE PROTEAN 2-INCH ALPHA/BETA COUNTING SYSTEM FOR GROSS
None No reference to any industry method.

Note: A complete list of WSCF analytical procedures and referenced regulatory or industry methods is available online at \\ap006\aspdocs\WSCF\Sample Mgmt\ProcedureMethodCrossReference.pdf. This document includes on-line links to full-text versions of the procedures and methods, where available.

w13qlog v1 18-apr-2006 07:36:31

W13q Worklist/Batch/QC Report for Group# WSCF20060211

WL#	S#	Batch	QC#	Tray Type	Sample#	Test
28354	1	28727	32596	BLANK		Strontium 89/90
28354	2	28727	32596	LCS		Strontium 89/90
28354	3	28727	32596	DUP	W060000492	Strontium 89/90
28354	4	28727	32596	SAMPLE	W060000492	Strontium 89/90

M8141-SLF-06-075

ATTACHMENT 3

SAMPLE RECEIPT INFORMATION

Consisting of 4 pages
Including cover page

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Waste Sampling and Characterization Facility
P.O. BOX 1970 S3-30, Richland, WA 99352
PHONE: (509) 373-7004/FAX: (509) 373-7134

ACKNOWLEDGMENT OF SAMPLES RECEIVED

Revised -A
(N Sample ID
KB 4/18/06

Groundwater Remediation Program

Richland, WA 99354
Attn: Steve Trent

Customer Code: GPP
PO#: 121640/ES10
Group#: 20060211
Project#: F06-013
Proj Mgr: Steve Trent A0-21
Phone: 373-5869

The following samples were received from you on 03/23/06. They have been scheduled for the tests listed beside each sample. If this information is incorrect, please contact your service representative. Thank you for using Waste Sampling and Characterization Facility.

Sample#	Sample Id	Tests Scheduled	Matrix	Sample Date
W060000492	B1HTJ7-A	GRP TRENT @SR89_90	Solid, or handle as if solid	03/21/06

Test Acronym Description

Test Acronym	Description
@SR89_90	Strontium 89/90

Fluor Hanford Inc. 04/19/06

CHAIN OF CUSTODY/SAMPLE ANALYSIS REQUEST

F06-013-001 PAGE 1 OF 1

COLLECTOR: Bill Peppin / Deb Alexander

COMPANY CONTACT: TRENT, SJ

TELEPHONE NO.: 373-5869

PROJECT COORDINATOR: TRENT, SJ

PRICE CODE: 8H

DATA TURNAROUND: 30 Days / 30 Days

SAMPLING LOCATION: BC Controlled Area

PROJECT DESIGNATION: BC Cribs - Sodium Iodide Standard Analysis

SAF NO.: F06-013

AIR QUALITY:

ICE CHEST NO.:

FIELD LOGBOOK NO.:

COA: 121640ES10

METHOD OF SHIPMENT: FEDERAL EXPRESS

SHIPPED TO: Eberline Services

OFFSITE PROPERTY NO.:

BILL OF LADING/AIR BILL NO.:

MATRIX*
A=Air
DL=Drum Liquids
DS=Drum Solids
L=Liquid
O=Oil
S=Soil
SE=Sediment
T=Tissue
V=Vegitation
W=Water
WI=Wipe
X=Other

POSSIBLE SAMPLE HAZARDS/ REMARKS

PRESERVATION: None

TYPE OF CONTAINER: G/P

NO. OF CONTAINER(S): 1

VOLUME: 60mL

SAMPLE ANALYSIS: Strontium-89,90 – Total Sr

SPECIAL HANDLING AND/OR STORAGE

20060211

SAMPLE NO.	MATRIX*	SAMPLE DATE	SAMPLE TIME
B1HTJ7	SOIL	3/16/06 21	1300 ✓

PGH 4/18/2006 P.D. Mix

3-21-06

CHAIN OF POSSESSION

RELINQUISHED BY/REMOVED FROM	DATE/TIME	RECEIVED BY/STORED IN	DATE/TIME
DA Alexander/Dalexander	3-21-06/1521	Refrigerator #3/M0745	3-21-06/1521
Refrigerator #3	3-23-06 11:25	RC Mahal/Rahul C. Mahal	3-23-06 11:25
R.C. Mahal/Rahul C. Mahal	3-23-06 1200	TA FRAZIER/Teresa Frazier	3/23/06 1200

SIGN/ PRINT NAMES

SPECIAL INSTRUCTIONS

Send example of BC Controlled Area Calibration Soil.

LABORATORY SECTION — RECEIVED BY — TITLE — DATE/TIME

FINAL SAMPLE DISPOSITION — DISPOSAL METHOD — DISPOSED BY — DATE/TIME

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WASTE SAMPLING AND CHARACTERIZATION FACILITY (WSCF)

NOTICE OF IMPROPER SAMPLE SUBMITTAL

Customer Name: Steve Trent

Sample ID: B1HTJ7 Date Received: 03-23-06

Project Contact: Steve Trent Phone Number: 373-5869

[X] Sample not iced.
[ ] Sample does not pass radiological screening.
[ ] Sample not accompanied by a Chain of Custody (COC) or Request for Special Analysis (RSA).
[ ] Improperly completed COC or RSA.
[ ] Sample information does not agree with documentation.
[ ] Handwriting is illegible.
[ ] Sample container broken/leaking.
[ ] Sample container not labeled/label unreadable.
[ ] Sample received with custody seal broken.
[ ] Sample improperly packaged.
[ ] Improper sample container for analyses requested.
[ ] Insufficient sample quantity for requested analyses.
[ ] Holding time exceeded.
[ ] Other (see below)

Comments: COC 3/23/06 F06-013-001

For information on proper sample submittal procedures, contact WSCF Sample Custodian at 373-7423, 373-7001, or Sample Receiving at 373-7019.

Signature: Teresa Thayer Date: 03-23-06

FIDLER Calibration

FIDLER Calibration

The FIDLER program is used to calibrate a FIDLER (Field Instrument for the Detection of Low-Energy Radiation) for measurement of plutonium contamination on the ground. However, the program can be applied to any instrument suitable for measuring external radiation levels and non-plutonium mixtures, e.g., using a Geiger-Mueller instrument for the measurement of ^{137}Cs ground contamination.

When measuring plutonium ground contamination, the FIDLER is typically calibrated for the 60-keV gamma ray from the ^{241}Am component of the mixture (typically of the order of 1000s of ppm by weight), or the low-energy x rays centered around 17 keV. Measurements using the x rays are very sensitive to overburden, e.g., rain, contamination fixative, dust, etc., and generally not recommended. Measurements using the 60-keV gamma from ^{241}Am are much less sensitive to the overburden effects due to their higher energy. FIDLER assumes that contamination lies entirely on the surface of the soil, characteristic of newly deposited activity. If significant weathering has occurred, a correction factor is required to account for the attenuation of the emitted photons as a function of soil depth. This correction factor should be based upon actual soil sample analyses.

Calibration of the FIDLER Detector

The standard FIDLER consists of a 12.7-cm diameter by 0.16-cm thick NaI(Tl) crystal. The detector entrance window is typically 0.025-cm thick beryllium. The crystal is connected to a photomultiplier tube, and the output of the tube is connected to a hand-held rate meter, or scaler.

A radiation detector can be calibrated by several methods for measuring surface contamination. As shown in Figure 1, the most obvious method is suspending the detector over a known area source. Here, every square meter of the source contains, for example, 1 μCi of ^{241}Am, and the counts per minute (cpm) indicated on the instrument is, by definition, the areal counting efficiency for ^{241}Am (cpm/[μCi-m2]). However, such a source is not practical in terms of size, cost, and transportability.

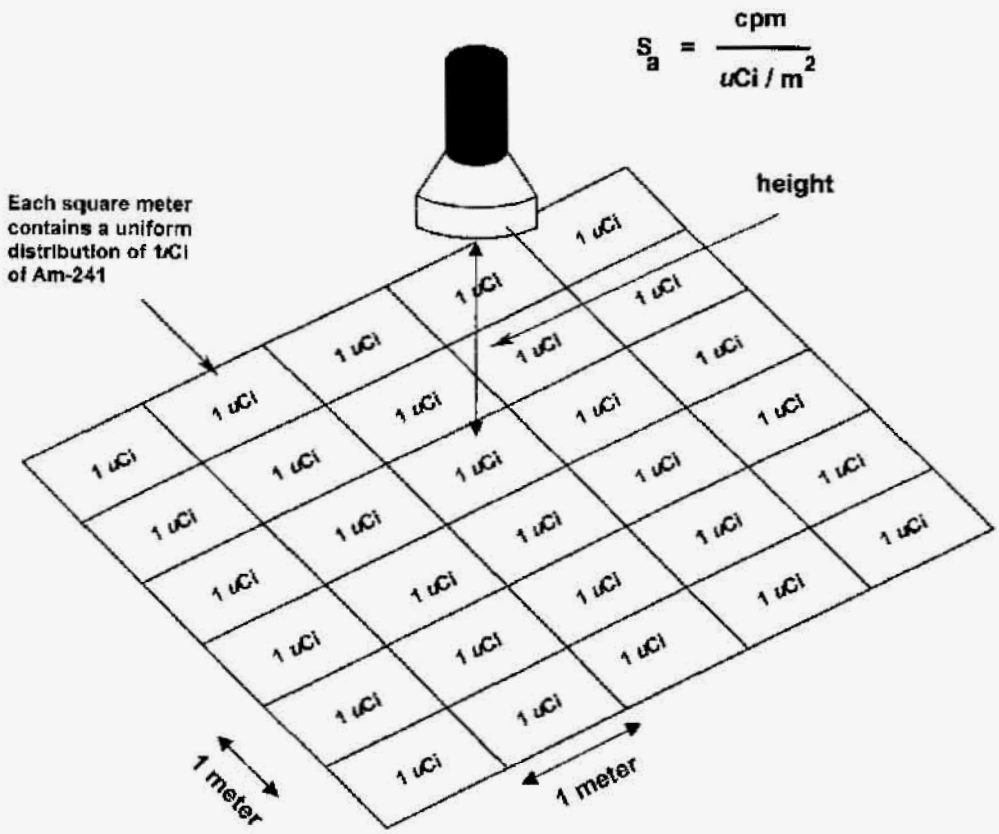


Figure 1.

Semi-infinite plane Am-241 check source.

The following procedure describes a method for calibrating a detector to measure surface contamination with a single-point check source. Figure 2 shows the six measurement positions required for this calibration procedure. The calibration method was originally intended for a standard FIDLER instrument, but the technique is applicable to any suitable detector and contamination, e.g., a 2-in. diameter x 2-in.-thick NaI(Tl) detection system for surveying ^{137}Cs ground contamination.

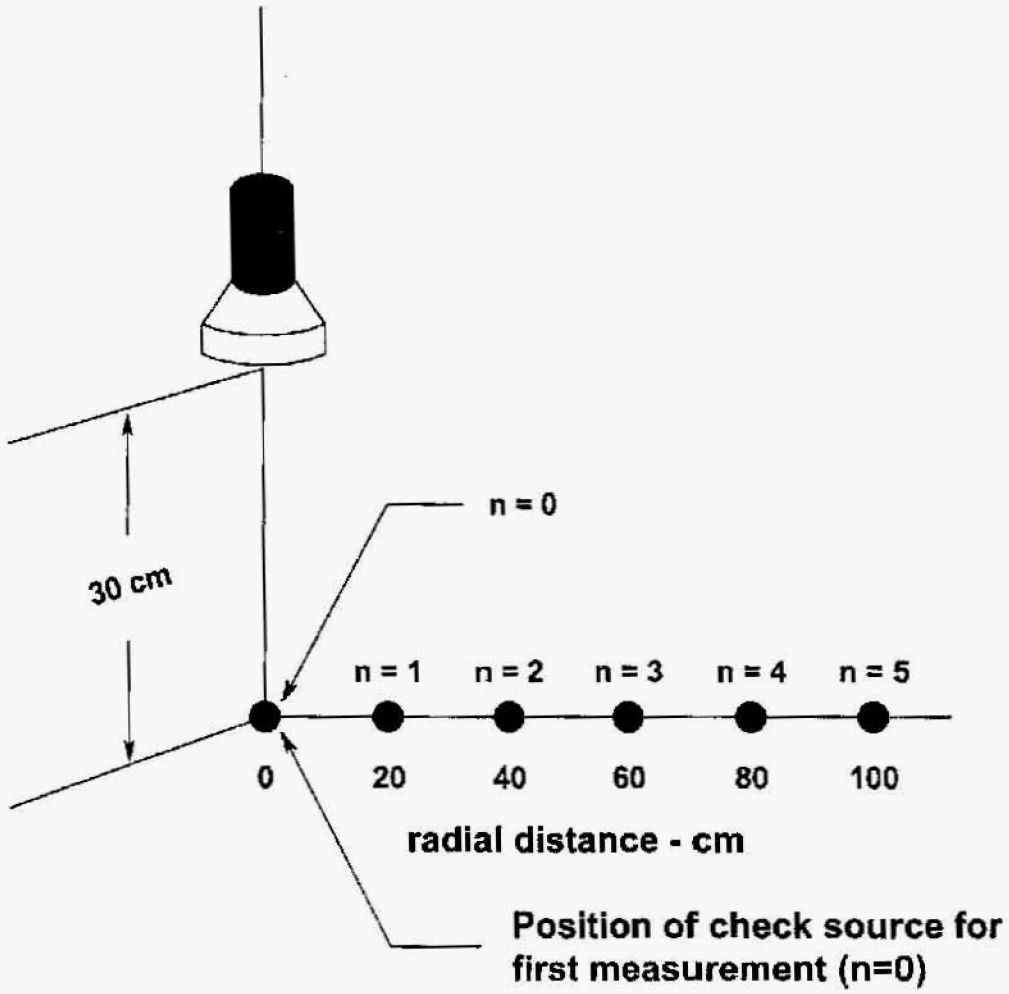


Figure 2.

Radial check source position .

The primary goal of the calibration procedure is determining the instrument's counting efficiency for an assumed uniform area contamination per square meter of surface. This parameter is referred to as the areal counting efficiency (*Sa*). This efficiency differs considerably from the simple point-source efficiency, which is commonly used to determine an instrument's sensitivity for locating small "point" sources. Here, we must account for the instrument's sensitivity for off-axis radiation sources and field of view. Figure 3 shows the count rate for a typical FIDLER system as a function of radial position of a 5.9-μCi ^{241}Am check source.

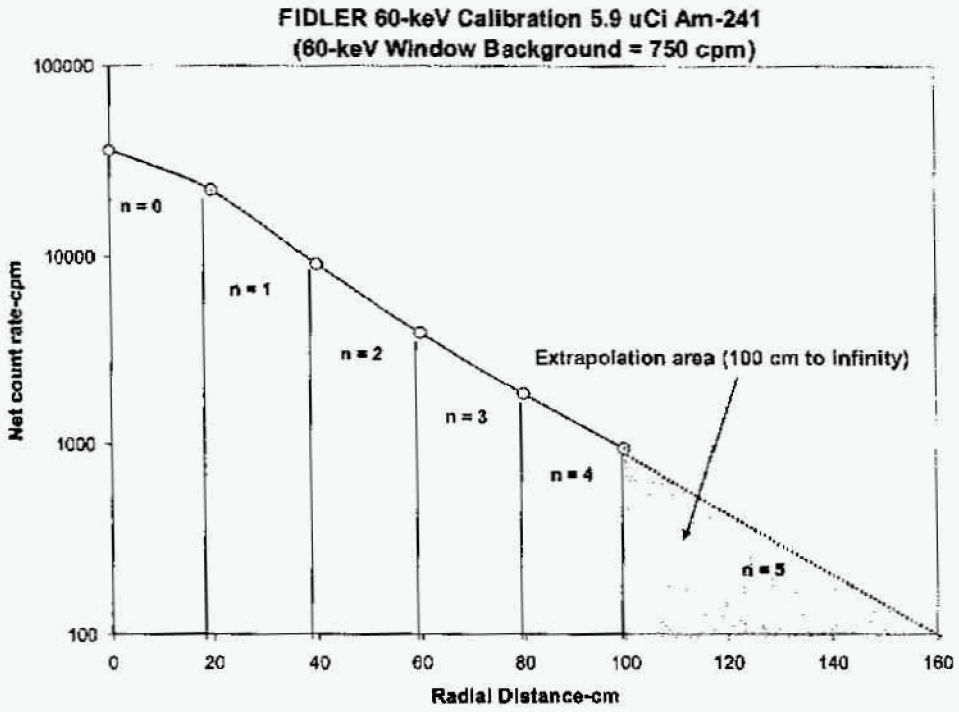


Figure 3. Typical FIDLER calibration data.

Determination of the Areal Counting Efficiency (S_a)

The FIDLER is suspended at height (h) above the ground. The FIDLER's areal counting efficiency (Sa) for 241Am (using the 60-keV gamma ray), from a uniform distribution over a circular area (A) of radius (R) is—

$$S_a = \frac{1}{q} \int C(r)\, dA \qquad \text{(Eq. 1)}$$

where:

q = Activity in area, dA (μCi).
$C(r)$ = Count rate from activity (q) in area, dA.

Because $dA = r\, dr\, d\theta$,

$$S_a = \int_0^{2\pi} \frac{1}{q} \int_0^R C(r)\, r\, dr\, d\theta \qquad \text{(Eq. 2)}$$

$$S_a = \frac{2\pi}{q} \int_0^R C(r)\, r\, dr \qquad \text{(Eq. 3)}$$

The determination of the areal counting efficiency requires the evaluation of the integral in Eq. 3. As shown in Fig. 2, the FIDLER program requires check source measurements at 6 locations (r0–r5), each location being radially offset by 20 cm.

The observed FIDLER count rate between any two adjacent calibration points, as a function of radial distance, is well represented by a simple exponential function of the form,

$$C(r) = ae^{br}$$

where:

- a = Y-axis intercept.
- b = Slope.
- r = Radial distance.

Letting $C(r) = aebr$, in Eq. 3,

$$S_a = \frac{2\pi}{q}\left[\sum_{n=0}^{4} a_n \int_{r_n}^{r_{n+1}} re^{b_n r}\, dr \;+\; a_4 \int_{r_5}^{\infty} re^{b_4 r}\, dr\right] \qquad \text{(Eq. 4)}$$

$$S_a = \frac{2\pi}{q}\left[\sum_{n=0}^{4} \frac{a_n}{b_n^2}\left[e^{b_n r_{n+1}}\left(b_n r_{n+1} - 1\right) - e^{b_n r_n}\left(b_n r_n - 1\right)\right] - \frac{a_4}{b_4^2} e^{b_4 r_5}\left(b_4 r_5 - 1\right)\right] \qquad \text{(Eq. 5)}$$

where:

$$\int re^{br}dr = \frac{e^{br}}{b^2}(br-1) \quad ,$$

$$b_n = \frac{\ln\left(\frac{C(r_n)}{C(r_{n+1})}\right)}{r_n - r_{n+1}} \quad , \quad \text{and}$$

$$a_n = C(r_n)e^{-b_n r_n} \quad .$$

This is the *Sa* value for a mixture consisting of 100% 241Am. Because we are interested in the *Sa* value for a plutonium mixture, we need to account for the activity fraction of 241Am in our actual sample mixture,

$$S_{mix} = \frac{S_a}{f} \quad , \quad \frac{\text{counts - m}^2}{\text{min - }\mu\text{Ci}_{\text{mix}}} \qquad \text{(Eq. 6)}$$

where:

f = the ratio of alpha µCi of mix to µCi of 241Am.

The f ratio is a function of the assumed mix and is automatically determined once you have either selected the default mix and age, default mix and user-input age, or input a specific mix and age. The value of f is always displayed with the final calibration data (computer display) and is stated as follows:

"1 microcurie of Am-241 = 8.66E+00 alpha µCi of MIX."

In this example, f = 8.66. Note: If you were actually measuring a mix of 100% 241Am, the f ratio = 1, and no adjustment of the *Sa* value is required. If you are calibrating the FIDLER using the 17-keV window, the x-ray abundance ratio of the 241Am check source to the plutonium mixture is automatically determined and used in calculating the 17-keV window efficiency. If you are measuring a specific nuclide, e.g., 137Cs, it is assumed your calibration source is identical to the "sample" mix, and again the f ratio is 1.

Once the areal counting efficiency has been determined for an instrument, a simple "spot check" calibration scheme based on the *K* ratio is possible. The *K* ratio is defined as the ratio (*K*) of the areal source counting efficiency (*Sa*) to the point source counting efficiency (*Sp*).

$$K = \frac{S_a}{S_p} \quad , \quad \mathrm{m}^2$$

(Eq. 7)

where:

S_a = cpm per µCi/m2.
S_p = cpm per µCi.

Once the *K* ratio has been determined for a particular instrument geometry, the ratio will remain relatively constant. The electronics might drift (e.g., the PRM-5-3 window shift away from the desired photopeak), but the system's *K* ratio will not be affected. In other words, the *Sa* and *Sp* can change, but their ratio will remain constant. The "quick" calibration consists of measuring the point source efficiency (*Sp*) with an 241Am check source. The FIDLER's areal counting efficiency is then calculated by multiplying *Sp* by the *K* ratio. Any changes in the detection system will be accounted for by the current *Sp* measurement. This allows for a quick field-calibration scheme. For example, a monitoring team can measure the point efficiency before and after a series of field measurements to confirm the status of the areal counting efficiency (*K* x *Sp*). This provides an "audit" trail of the detector efficiency for post-survey data reduction and documentation.

The Limit of Sensitivity (LOS) is reported with a Type 1 and Type 2 error (alpha and beta) equal to 0.05. The following determines the LOS.

Scaler: (from Currie, 1975)

$$LOS = \frac{2.7 + 4.65\sqrt{r_b / t_s}}{S_a} \quad , \quad \mu\mathrm{Ci}$$

(Eq. 8)

Rate Meter:

$$LOS = \frac{3.3\sqrt{r_b / 2RC}}{S_a} \quad , \quad \mu\mathrm{Ci}$$

(Eq. 9)

where:

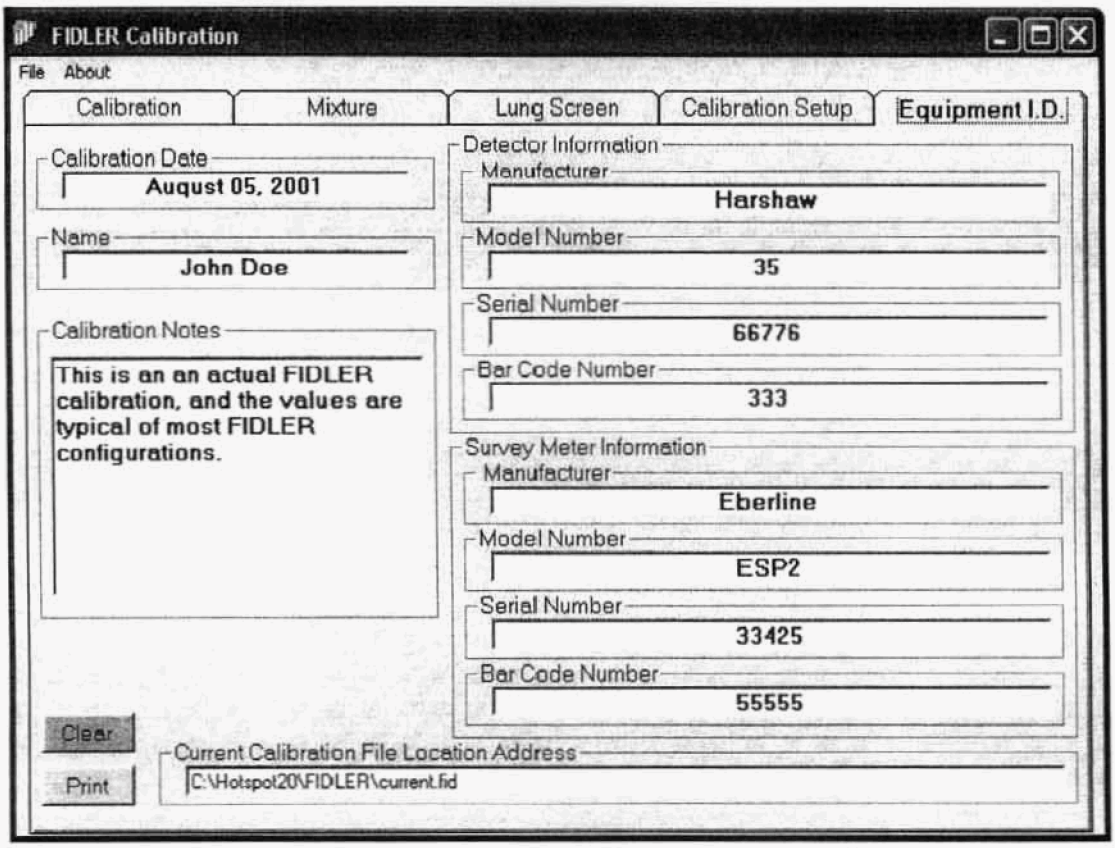
RC = Rate meter time constant (min).
rb = Background count rate (cpm).
ts = Sample counting time (min).
Sa = Areal counting efficiency (cpm/[µCi/m2]).

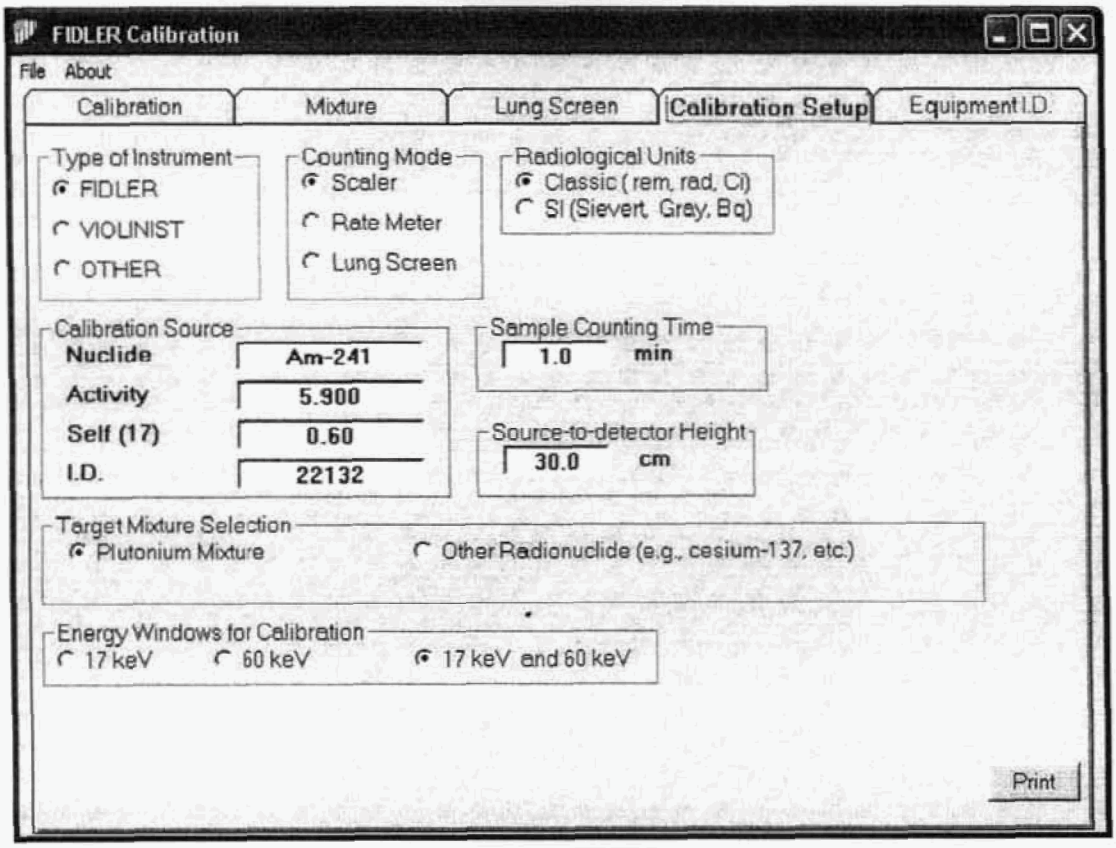
The standard deviations of the areal counting efficiency and *K* factor are also output to the calibration information display. If you are using a weak check source, short integration time, etc., this will be reflected in a large standard deviation.

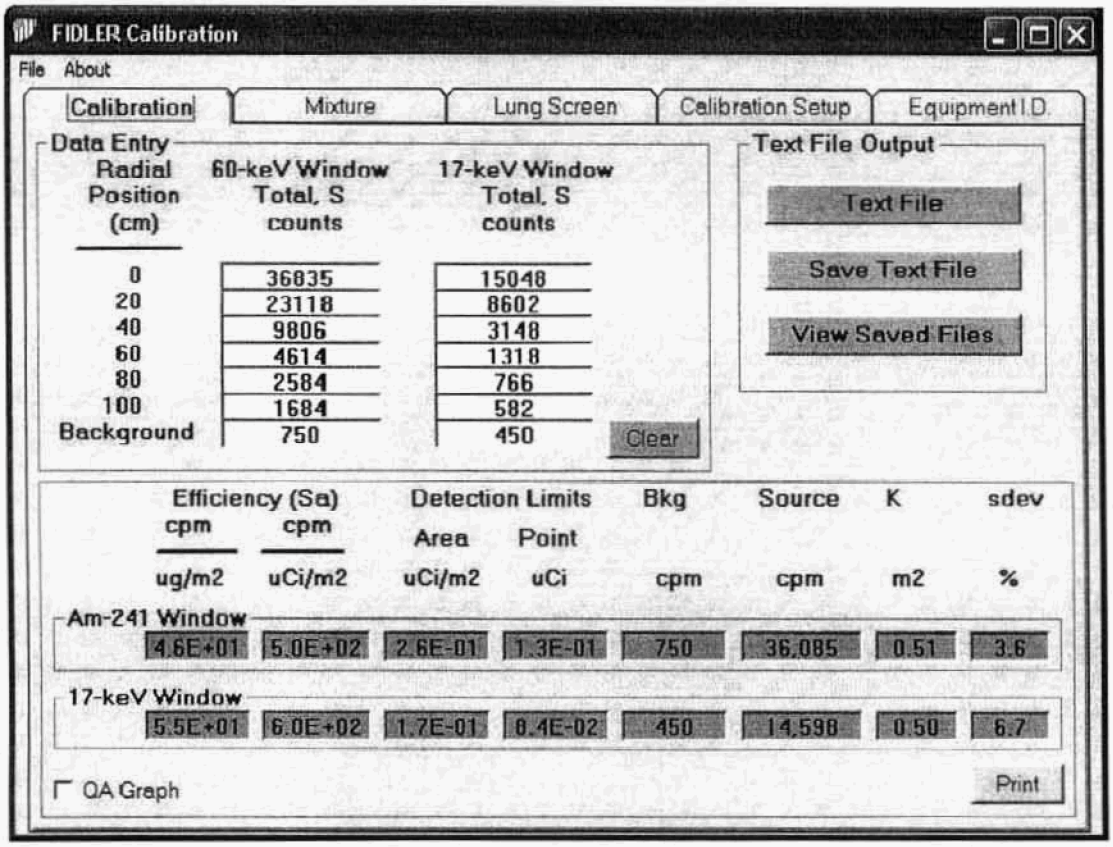
Example FIDLER Calibration

A FIDLER will be used to survey a contaminated area following a recent event involving weapons-grade plutonium. No information on the plutonium mixture is available, but it is known that the mixture is 30 years old (i.e., 30 years since processing). The following data were obtained using the FIDLER at a ground-to-detector distance of 30 cm. Determine the FIDLER calibration constants.

Calibrate the FIDLER using a 5.9-μCi Am-241 check source. It is important to confirm the self-absorption characteristics of the source (e.g., due a paper label covering the activity material). The 60-keV gamma rays will not be appreciably attenuated in most check sources, and the absorption factor is assumed to be 1.00, i.e., SELF(60) = 1.00. However, the 17-keV x-ray absorption factor can be significant and is required information for the FIDLER calibration (unless you are only interested in 60-keV measurements). If you do not know the SELF(17) factor, you can always update the calibration data at a later date. In this example, we will assume a 17-keV self-absorption factor of 60%, i.e., SELF (17) = 0.60. In other words, 60% of the 17-keV x rays emitted and directed towards the FIDLER detector reach the detector (40% are attenuated by the source itself). The FIDLER code assumes a constant thickness of "overburden" material associated with the check source and automatically adjusts the increase in self-absorption path length as the FIDLER is position at increasing radial distances during the calibration procedure.


FIDLER Calibration
File About
Calibration
Mixture
Lung Screen
Calibration Setup
Equipment I.D.
Calibration Date
Auqust 05, 2001
Name
John Doe
Calibration Notes
This is an an actual FIDLER calibration, and the values are typical of most FIDLER configurations.
Detector Information
Manufacturer
Harshaw
Model Number
35
Serial Number
66776
Bar Code Number
333
Survey Meter Information
Manufacturer
Eberline
Model Number
ESP2
Serial Number
33425
Bar Code Number
55555
Clear
Print
Current Calibration File Location Address
C:\Hotspot20\FIDLER\current.fid


FIDLER Calibration
File About
Calibration
Mixture
Lung Screen
Calibration Setup
Equipment I.D.
Type of Instrument
FIDLER
VIOLINIST
OTHER
Counting Mode
Scaler
Rate Meter
Lung Screen
Radiological Units
Classic (rem, rad, Ci)
SI (Sievert, Gray, Bq)
Calibration Source
Nuclide
Am-241
Activity
5.900
Self (17)
0.60
I.D.
22132
Sample Counting Time
1.0
min
Source-to-detector Height
30.0
cm
Target Mixture Selection
Plutonium Mixture
Other Radionuclide (e.g., cesium-137, etc.)
Energy Windows for Calibration
17 keV
60 keV
17 keV and 60 keV
Print


FIDLER Calibration
File About
Calibration
Mixture
Lung Screen
Calibration Setup
Equipment I.D.
Data Entry
Radial Position (cm)
60-keV Window Total, S counts
17-keV Window Total, S counts
0 36835 15048
20 23118 8602
40 9806 3148
60 4614 1318
80 2584 766
100 1684 582
Background 750 450
Clear
Text File Output
Text File
Save Text File
View Saved Files
Efficiency (Sa) cpm ug/m2
Efficiency (Sa) cpm uCi/m2
Detection Limits Area uCi/m2
Detection Limits Point uCi
Bkg cpm
Source cpm
K m2
sdev %
Am-241 Window
4.6E+01 5.0E+02 2.6E-01 1.3E-01 750 36,085 0.51 3.6
17-keV Window
5.5E+01 6.0E+02 1.7E-01 8.4E-02 450 14,598 0.50 6.7
QA Graph
Print

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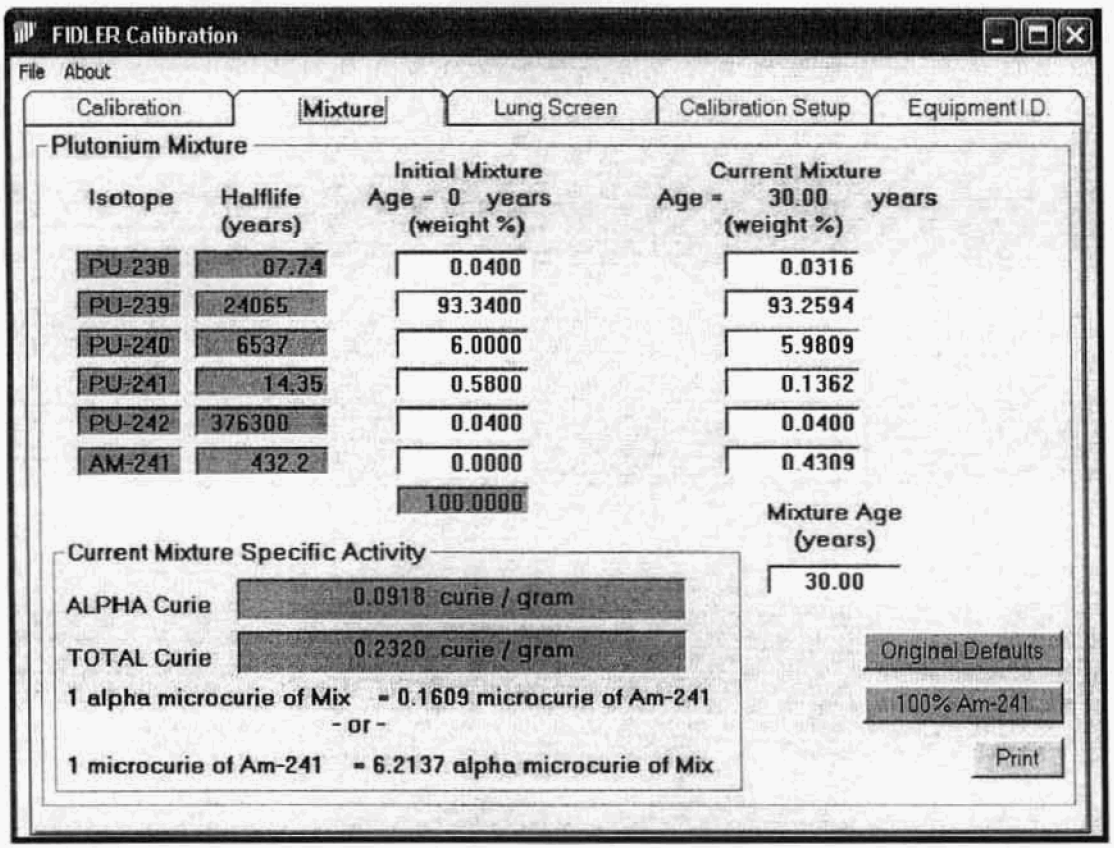

Hotspot FIDLER Text File Output

Hotspot FIDLER Calibration Information

Report Date	:	Nov 20 2006 03:24 PM
Calibration Date	:	August 15, 2006
Target Mix	:	Other Nuclide Check Source
Radionuclide	:	Cs-137
Detector Barcode Number	:	property # WD 46885
Meter Barcode Number	:	property # WD 46885
Detector Manufacturer	:	Ortec
Detector Model Number	:	DigiBase Multichannel Analyzer attached to:
Detector Serial Number	:	4 X 4 X 16 inch NaI Detector
Meter Manufacturer	:	Ortec
Meter Model Number	:	Search System Software loaded onto:
Meter Serial Number	:	Panasonic Toughbook Laptop Computer
Check Source I.D.	:	WSCF20060197
Calibration Date	:	August 15, 2006
Calibrated by	:	Jeff Pappin
Check Source Activity (uCi):		2.930E+00
Check Source 17-keV Self	:	6.000E-01
Sample Counting Time (minutes)	:	1.000E+00
Detector Height (cm)	:	2.800E+01

Cs-137 Window Information:

Background (cpm)	:	58,986
Areal Limit of Sensitivity (uCi/m2)	:	3.7E-02
Point Limit of Sensitivity (uCi)	:	3.2E-02
K-factor (m2)	:	0.85

Counting Data:

0-cm:	163758.000
20-cm:	138408.000
40-cm:	102072.000
60-cm:	80748.000
80-cm:	72720.000
100-cm:	64998.000

Instrument Type :Other
Window Option:Only 60 keV
Units:Classic
This is a 4x4x16 inch NaI calibration. Measurements taken outside with 6 source bottles buried flush to ground surface, detector is mounted to Gator. MCA total counts, full spectrum. Ten 1 second counts x 6 = 1 minute.

Detector Calibration Results

Cs-137 Window Information:

Cs-137 Detector Efficiency (cpm/(uCi/m2)):		3.0E+04
Cs-137 Detector Areal LOS (uCi/m2)	:	3.7E-02
Cs-137 Detector Point LOS (uCi)	:	3.2E-02
Cs-137 Detector Background Rate (cpm)	:	58,986
Cs-137 Detector Check Source Rate (cpm)	:	104,772
Cs-137 Detector K-Factor (m2)	:	0.85
Cs-137 Detector K-Factor sdev (%)	:	1.6

Calibration | No Mixture | Lung Screen | Calibration Setup | **Equipment I.D.**

Calibration Date
August 15, 2006

Name
Jeff Pappin

Calibration Notes
This is a 4x4x16 inch NaI calibration. Measurements taken outside with 6 source bottles buried flush to ground surface, detector mounted to Gator. MCA, total counts, full spectrum. Ten 1 sec counts x 6 = 1 minute.

Detector Information

Manufacturer
Ortec

Model Number
DigiBase Multichannel Analyzer attached to:

Serial Number
4 X 4 X 16 inch NaI Detector

Bar Code Number
property # WD 46885

Survey Meter Information

Manufacturer
Ortec

Model Number
Search System Software loaded onto:

Serial Number
Panasonic Toughbook Laptop Computer

Bar Code Number
property # WD 46885

Current Calibration File Location Address
C:\Hotspot20\FIDLER\Nov 20 2006 4 X 4 X 16 inchGator.fid

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Calibration | No Mixture | Lung Screen | **Calibration Setup** | Equipment I.D.

Type of Instrument
- ○ FIDLER
- ○ VIOLINIST
- ◉ OTHER

Counting Mode
- ◉ Scaler
- ○ Rate Meter

Radiological Units
- ◉ Classic (rem, rad, Ci)
- ○ SI (Sievert, Gray, Bq)

Calibration Source
- **Nuclide**: Cs-137
- **Activity (uCi)**: 2.930
- **I.D.**: WSCF20060197

Sample Counting Time
- 1.0 min

Source-to-detector Height
- 28.0 cm

Target Mixture Selection
- ○ Plutonium Mixture
- ◉ Other Radionuclide (e.g., cesium-137, etc.)

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Calibration | No Mixture | Lung Screen | Calibration Setup | Equipment I.D.

Data Entry

Radial Position (cm)	Total, S counts
0	163758.000
20	138408.000
40	102072.000
60	80748.000
80	72720.000
100	64998.000
Background	58.986

Text File Output

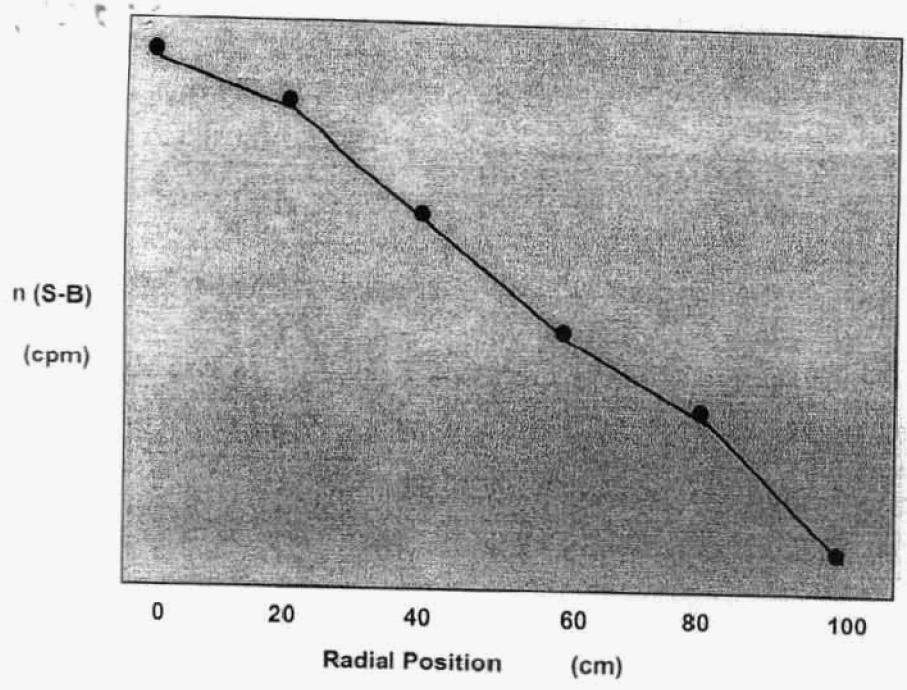
Text File

Save Text File

View Saved Files

Efficiency (Sa) cpm / uCi/m2	Detection Limits Area uCi/m2	Detection Limits Point uCi	Bkg cpm	Source cpm	K m2	sdev %
3.0E+04	3.7E-02	3.2E-02	58986	104.772	0.85	1.6

☐ QA Graph


n (S-B)
(cpm)
0
20
40
60
80
100
Radial Position
(cm)